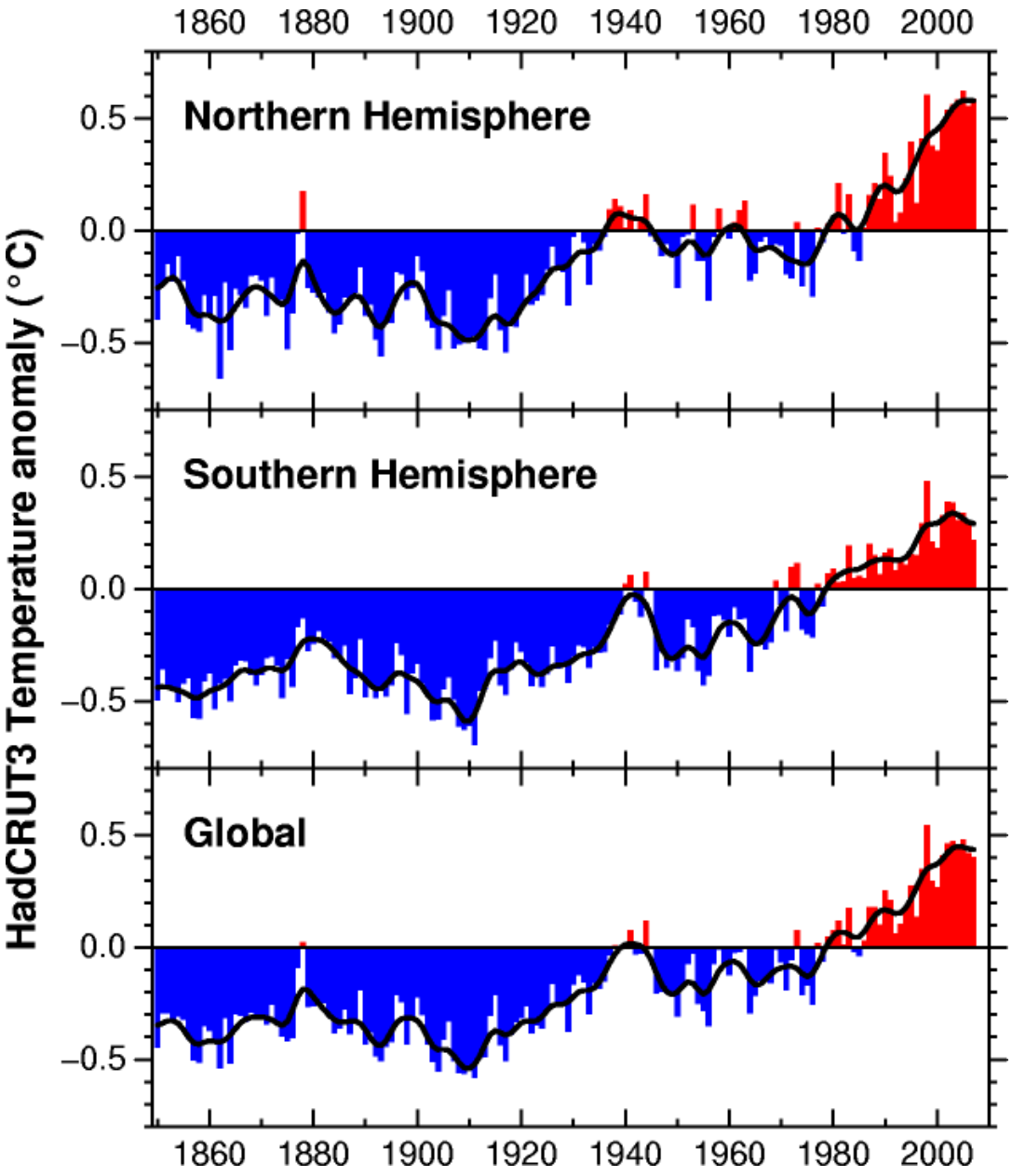
Ask Dr. SOO:

Q.: Dr. SOO, is the planet really getting warmer, or is this just a fantasy created by environmental wackos in a ploy to undermine US power? –Curious in Montana.

A.: Curious, the planet really has been warmer the last few decades than it has been previously. Consider the following data from the Hadley Center and Climate Research Unit in England:



This plots the latest global average temperature from 1850 through the end of 2007. The data plotted are the result of a careful analysis and quality control methodology applied to thousands of worldwide land-based and sea-surface temperature measurements, including

our humble little surface station at the airport in Glasgow. This is probably the most accurate and respected measure of global surface temperature. From the plot of global temperature (bottom panel), there was a clear warming trend from about 1910 to 1940 and another one from about 1970 to the present. We are currently about 1.0°C (2°F) warmer than we were in the 1850-1910 time period. Another point from this plot is that the global temperature varies gradually. Even if we began a cooling trend for some reason, we would be above normal for quite some time.

Some would argue that this warming could be due to not subtracting the effects of urban heat islands. Many surface measuring stations have seen urban development around them over the decades, leading to warmer local temperatures just from the addition of asphalt and concrete. This may have some impact; however, ocean temperatures alone have also warmed in much the same way as land temperatures, and there is no urban heat island in the oceans. So, while you may disagree with the political motives of those advertising global warming, you should probably accept the fact that the planet has warmed some.

On the other hand, the data above do not support the acceleration of climate change that you sometimes hear about, at least so far. The record warm global temperature actually occurred in1998; and 2007 was the coolest year globally in seven years.

Q.: OK, maybe we are warmer, but isn't climate change just a natural phenomena that humans are powerless to affect one way or the other? --Curious

A.: Curious, you are certainly correct that climate change occurs naturally. The climate has been changing from warm to cool extremes for countless centuries before humans came along. On the other hand, humans can change things. The warming trend over the last century is coincident with an increase in carbon dioxide (CO_2) in the atmosphere over the same period. Carbon dioxide is fairly easy to measure accurately, and we know that humans (by burning carbon sources for fuel) emit more than enough carbon dioxide to account for the increase in the atmosphere. The CO_2 people put into the atmosphere is gradually removed by natural processes such as plant growth. These natural processes simply haven't kept up with the addition of CO_2.

On the other hand, CO_2 is a trace constituent of the atmosphere (accounting for only 0.04% of the air), and it is not obvious that increasing the concentration will have much impact. That CO_2 matters at all to climate is because of complex feedbacks in the climate system. The theory is that a CO_2 increase bumps surface temperature up slightly due to what is known as the "greenhouse effect", whereby CO_2 molecules retain heat like a blanket over the earth. This slight increase in temperature leads to an increase in water vapor in the atmosphere. Water vapor is by far the strongest greenhouse gas, and it is the increase in water vapor that leads to most of the warming. There are other positive feedbacks, as well, such as a decrease in ice cover and an increase in desert cover, both of which lead to warming. There are also negative feedbacks such as cloud cover and plant growth. This whole process is very complicated and difficult to nail down precisely. However, computer models of the atmosphere (developed by numerous independent

groups), which use the most advanced and powerful computers the world has ever seen, have been created to sort all this out. These models broadly agree that the recent warming trend is not just coincident with the increase in CO_2, but is caused by it. These models constitute our best current scientific understanding of the climate. The IPCC report (from that UN-sponsored committee that won the Nobel Peace Prize last year) stated that the consensus was that recent warming was caused by humans with a better than 90% certainty (or at most 10% uncertainty). The 10% uncertainty is because scientist account for the possibility that they are missing something. Climate scientists have been studying their models, fixing problems with them, and validating them against observations for a long time. They are now pretty confident about them, at least so far as CO_2 is concerned.

Q.: All right, Dr. SOO, even if I am willing to buy the human-carbon dioxide-global warming link as probable, how can you guys predict the climate for the next 50 years if you can not predict next week's weather? –Curious

A.: Good question, Curious. As humans are expected to continue to emit CO_2 for the next century, it is logical that global warming from CO_2 might be expected to continue, and the climate models show this. The idea is that climate, being the average of weather, is more forecastable than the chaotic day-to-day weather. However, predictions of the future are inherently fraught with difficulty, as any weather forecaster knows.

Any forecast can be wrong. Even if the climate models are all exactly right physically, humans could render them wrong by simply spending trillions of dollars to remove CO_2 from the atmosphere, thus cooling the planet. The models can't account for the vagaries of human behavior.

There are other things the models don't or can't account for. If an asteroid smashes into the earth, kicking-up a cloud of dirt that blots out the sun for 20 years, then all bets are off. A similar thing could happen from a series of large volcanic eruptions or a nuclear war. Still, those things are not probable, and haven't happened in recent centuries. Something a little more likely to confound climate models might be an increase in global dimming from air pollution driven by world-wide economic development. Models do not account for this because no one knows how much air pollution to expect. In recent years, the global air has actually been cleaner, leading to an increase in global warming and there is no clear reason to expect this to reverse, but it is not out of the question. Another thing which the models don't include that could have some effect is a variation in solar output. Historically, periods of low solar output (as indicated by a reduction in sun spots) have coincided with cool periods for the global climate. The Little Ice Age 300 years ago is the best example. It is not known why this is the case since the fluctuation in solar output is so small that it is not clear that it should matter. Long term solar behavior can not now be forecast, so this is another wild card.

One other thing about forecasting with climate models is that they have been built by studying the past climate, and the future may be different in some way that causes subtle difficulties for the models. Ocean currents could be different, the distribution of glaciers

could be different, the amount of CO_2 may be different, and so on. Just because the climate models have accurately modeled the past climate, it is not clear that they will work as well in the future when some of the parameters will be different from what we've seen in the past.

The bottom line is that a model forecast is good so long as it accurately captures the physics, nothing unexpected by the model occurs, and the thing being forecast does not behave chaotically (like the weather).

So, Dr. SOO will say that while the climate models may be 90% accurate in their understanding of past and current climate, predictions of future climate are less accurate. But because of the success models have had in describing past climate, and accounting for the recent warming trend in particular, it behooves us to pay attention to their forecasts; they may well be right.